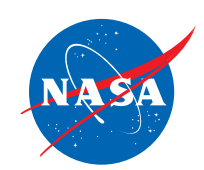


# Examining Hermeticity of UB Packages with Lid Seal Voids

Lyudmyla Ochs

NASA GSFC EEE Parts, Photonics and Assembly Branch

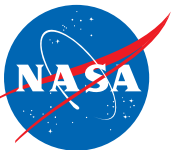
To be presented at MRQW February 10, 2022



# MIL-STD-883 Radiography Lid Seal Void Criteria

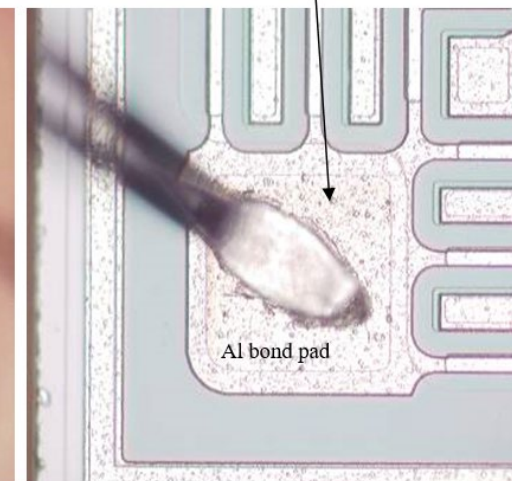
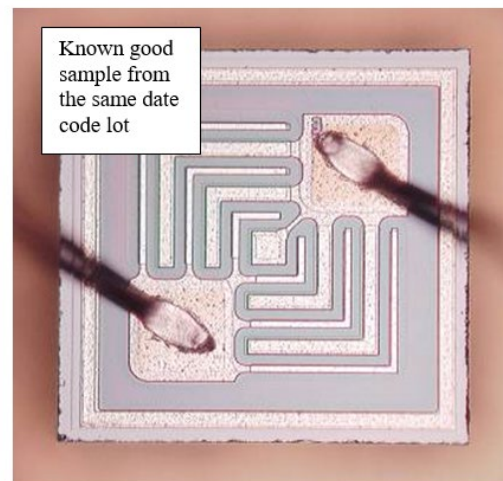
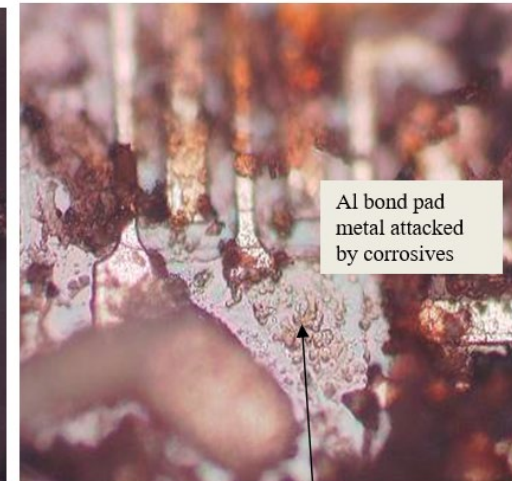
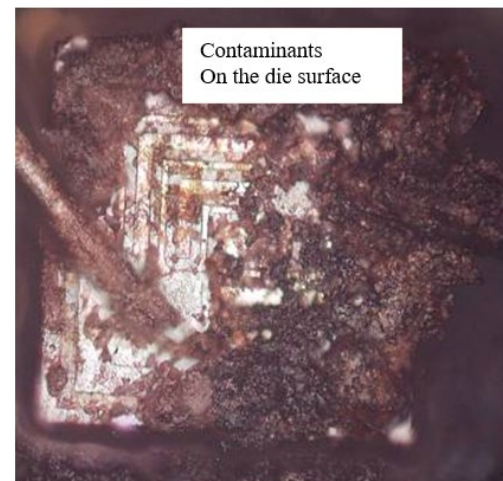
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- MIL-STD-883 TM 2012 Radiography has a lid seal void criteria
  - 3.10.2.2.e: Any device wherein the integral lid seal is not continuous or is reduced from its designed sealing width by more than 75 percent. Width reduction to less than 75% may be the result of either a single void or a combination of voids in the same width area
  - This applies to packages with solder seals, where a ring of solder is used on the perimeter of the lid to bond lid to the package
- It is not uncommon to observe parts that are hermetic per MIL-STD-883 TM 1014, but fail the lid seal void criteria, resulting in rejection of devices
- The purpose of this presentation is to
  - Share examples of packages with lid seal voids, their hermeticity and IGA results
  - Share results of a test for lid seal void integrity on units with lid seal voids failing MIL-STD-883 TM 2012 3.10.2.2.e criteria



# How Non-Hermetic Parts Can Fail

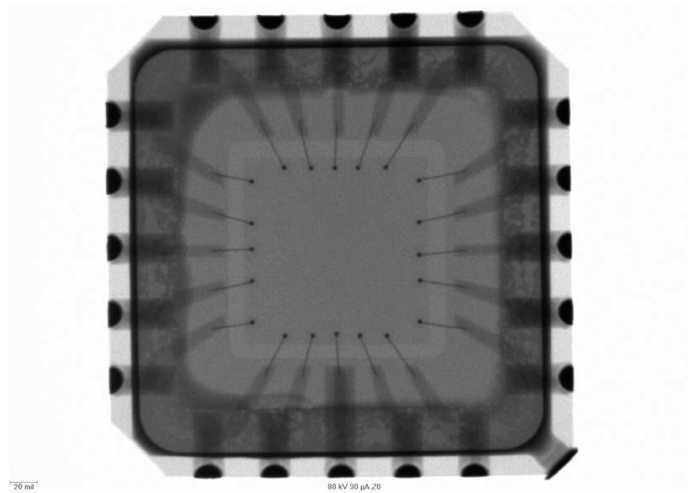
- Provided here as example of a type of failure that can occur if a package loses hermeticity
- This device package was non-hermetic, but mistakenly was placed on a board and operated
- Part operated for ~300 hours, before failing as electrical short-circuit
- Cause of failure: corrosive materials entered the package after manufacturing and during board assembly, corroding aluminum on bond pads, and developing conductive paths between collector, emitter and base





# Examples of Lid Seal Voids (1)

- Voids >90% of the lid seal
- Passed hermeticity
- Passed IGA



SAMPLE ID		58	144
Pass/Fail		PASS	PASS
Inlet Pressure	torr	3.0	3.3
Sys. Pressure	torr	4.3e-8	4.9e-8
Sample Temp.	°C	101.1	100.0
Volume	atm cc	0.014	0.015
Nitrogen	ppmv	997,819	997,164
Oxygen	ppmv	ND	ND
Argon	ppmv	220	564
Carbon Dioxide	ppmv	642	710
Moisture	ppmv	56	70
Hydrogen	ppmv	1,263	1,491
Methane	ppmv	ND	ND
Ammonia	ppmv	ND	ND
Helium	ppmv	ND	ND
Fluorocarbon	ppmv	ND	ND

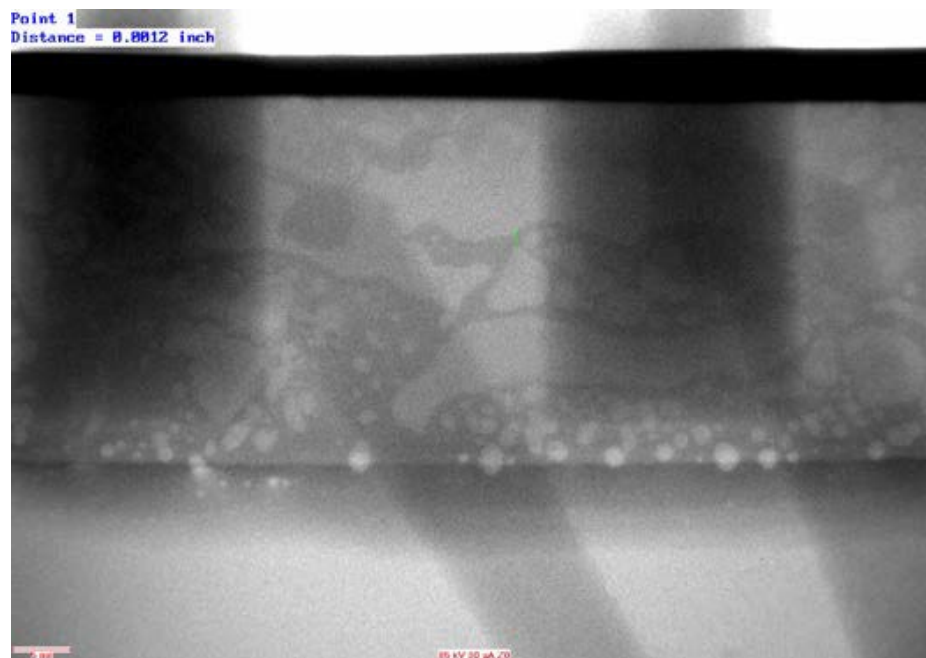
Optical image of the device (part markings removed) X-Rays of the package showing void in solder lid seal

IGA results of three packages with lid seals showing voids >90%  
IGA results show a hermetically sealed device



# Examples of Lid Seal Voids (1)

- Voids >90% of the lid seal
- Passed hermeticity
- Passed IGA

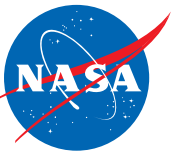


*X-Rays of the package showing void in solder lid seal. Void covers 93% of seal*

SAMPLE ID		58	144
Pass/Fail		PASS	PASS
Inlet Pressure	torr	3.0	3.3
Sys. Pressure	torr	4.3e-8	4.9e-8
Sample Temp.	°C	101.1	100.0
Volume	atm cc	0.014	0.015
Nitrogen	ppmv	997,819	997,164
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Fluorocarbon	ppmv	ND	ND

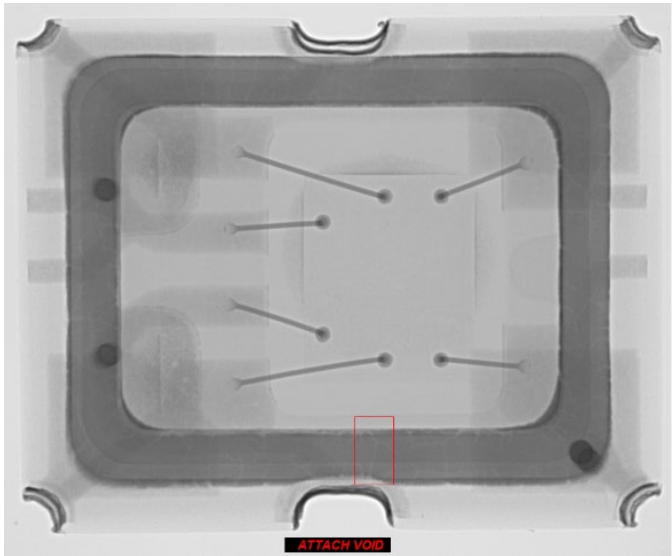
*IGA results of three packages with lid seals showing voids >90%  
IGA results show a hermetically sealed device*





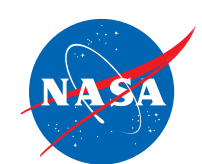
# Examples of Lid Seal Voids (2)

- Voids >99% of the lid seal
- Passed hermeticity
- Passed IGA



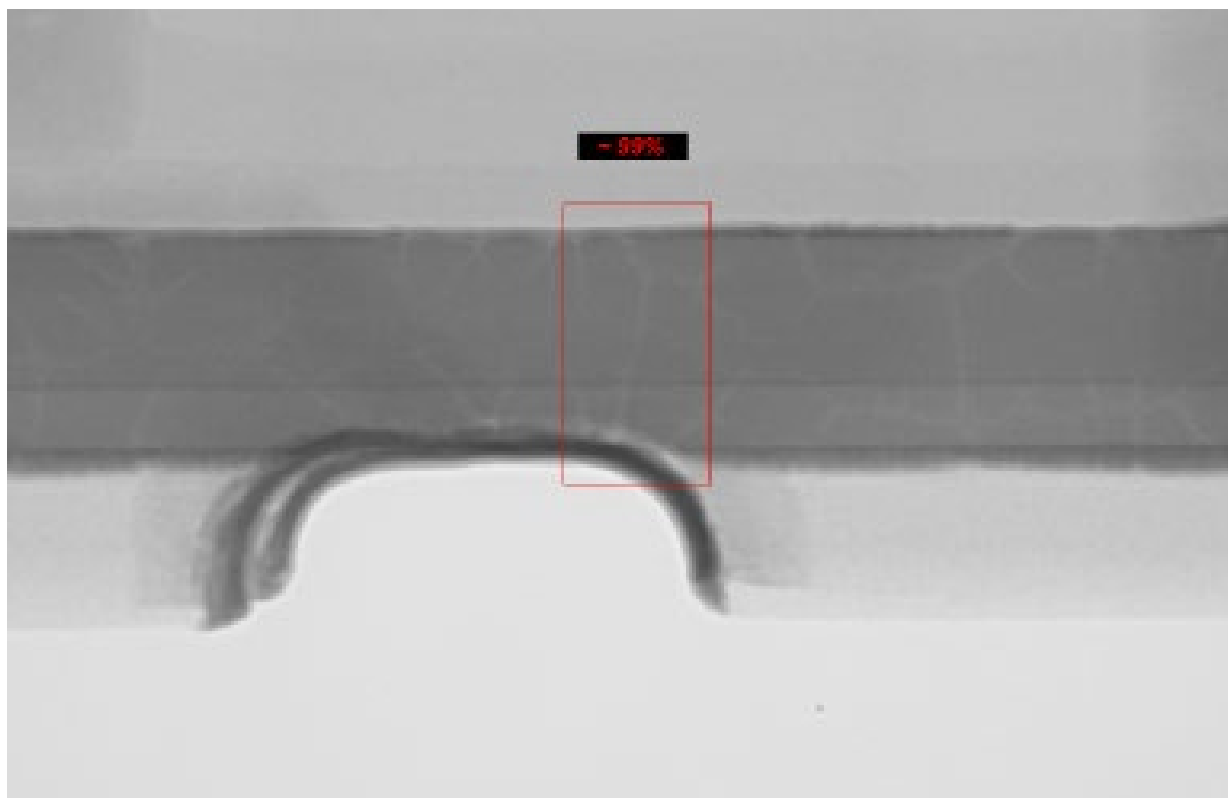
SAMPLE ID		3	4	5
Pass/Fail		PASS	PASS	PASS
Inlet Pressure	torr	N/A	N/A	N/A
Sys. Pressure	torr	4.1e-6	3.9e-6	4.2e-6
Sample Temp.	°C	99.4	99.3	99.6
Relative Humidity	RH%	0.1	0.1	0.2
Volume	cc-atm	0.001	0.001	0.001
Nitrogen	ppmv	995,947	996,059	995,435
Oxygen	ppmv	ND P	ND P	ND P
Argon	ppmv	44	59	59
Carbon Dioxide	ppmv	2,834	3,179	2,689
Moisture	ppmv	962 P	618 P	1,652 P
Hydrogen	ppmv	187	85	165
Methane	ppmv	ND	ND	ND
Ammonia	ppmv	ND	ND	ND
Helium	ppmv	ND	ND	ND
Fluorocarbon	ppmv	ND P	ND P	ND P
UNKNOWN	ppmv	26	ND	ND

IGA results of three packages with lid seals showing voids >99%  
IGA results show a hermetically sealed device



# Examples of Lid Seal Voids (2)

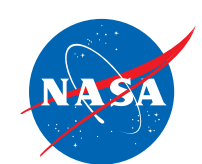
- Voids >99% of the lid seal
- Passed hermeticity
- Passed IGA



*X-Rays of the package showing void in solder lid seal*

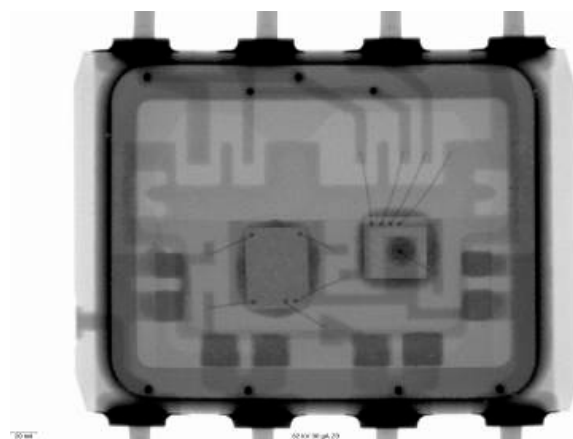
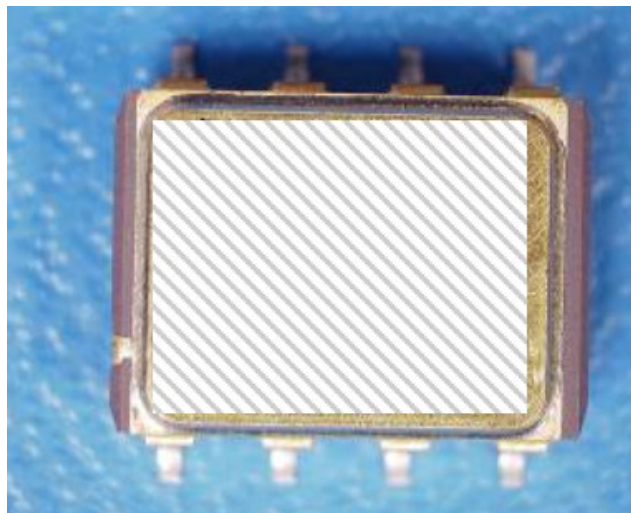
SAMPLE ID		3	4	5
Pass/Fail		PASS	PASS	PASS
Inlet Pressure	torr	N/A	N/A	N/A
Sys. Pressure	torr	4.1e-6	3.9e-6	4.2e-6
Sample Temp.	°C	99.4	99.3	99.6
Relative Humidity	RH%	0.1	0.1	0.2
Volume	cc-atm	0.001	0.001	0.001
Nitrogen	ppmv	995,947	996,059	995,435
Oxygen	ppmv	ND P	ND P	ND P
Argon	ppmv	44	59	59
Carbon Dioxide	ppmv	2,834	3,179	2,689
Moisture	ppmv	962 P	618 P	1,652 P
Hydrogen	ppmv	187	85	165
Methane	ppmv	ND	ND	ND
Ammonia	ppmv	ND	ND	ND
Helium	ppmv	ND	ND	ND
Fluorocarbon	ppmv	ND P	ND P	ND P
UNKNOWN	ppmv	26	ND	ND

*IGA results of three packages with lid seals showing voids >99%  
IGA results show a hermetically sealed device*



# Examples of Lid Seal Voids (3)

- Voids >80% of the lid seal
- Passed hermeticity
- Passed IGA
  - Note on IGA, the fluorocarbon values appear above the limit, but does not appear to be fluorocarbon ingress during gross leak testing



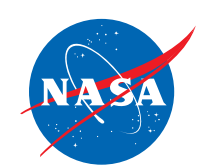
PART SERIAL	119	184	193
INLET TEMP	100.4 C	100.9 C	101.4 C
INLET PRESSURE	0.025 Torr	0.029 Torr	0.028 Torr
H	0.0000	0.0000	0.0000
HE3	0.0000	0.0000	0.0000
HE4	0.0000	0.0001	0.0001
CH4	6.6009	6.1673	6.8369
H2O	1.0924	0.4435	0.4849
NE20	0.0000	0.0000	0.0000
NE22	0.0000	0.0000	0.0000
N	91.1979	92.0403	91.2011
CO	0.0000	0.0000	0.0000
O	0.0538	0.2804	0.1127
AR	0.0053	0.0161	0.0018
CO2	0.2584	0.1915	0.2617
Total Hydrocarbons	0.6257	0.5821	0.7802
Fluorocarbons	0.0075	0.0027	0.0143
NH3	0.1580	0.2762	0.3062
KR	0.0000	0.0000	0.0000
XE	0.0000	0.0000	0.0000

Optical image of the device (part markings removed)

X-Rays of the package showing void in solder lid seal

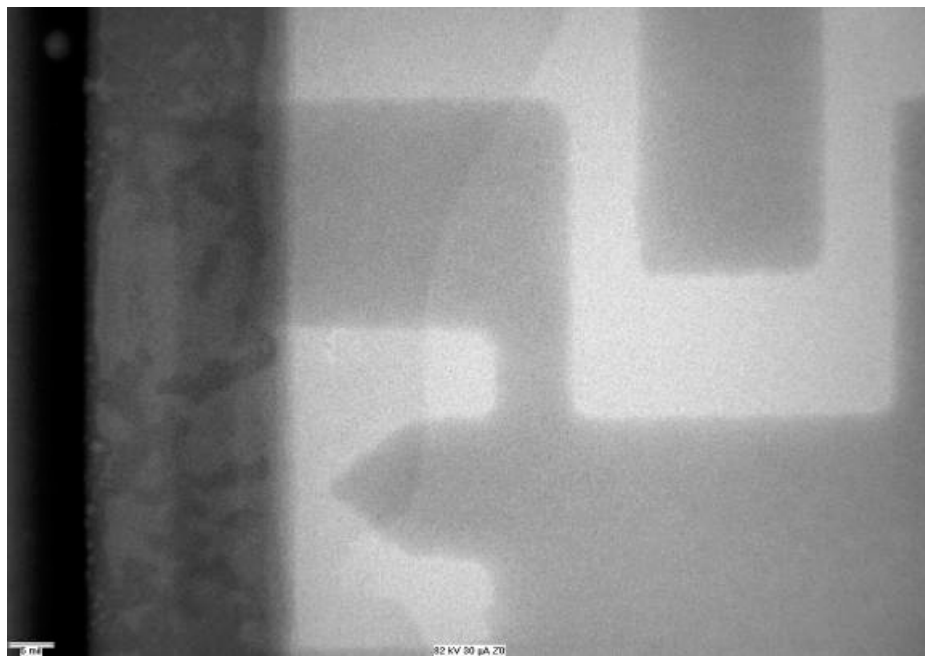
IGA results of three packages with lid seals showing voids >80%  
IGA results show a hermetically sealed device





# Examples of Lid Seal Voids (3)

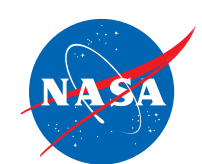
- Voids >80% of the lid seal
- Passed hermeticity
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  - Note on IGA, the fluorocarbon values appear above the limit, but does not appear to be fluorocarbon ingress during gross leak testing



*X-Rays of the package showing void in solder lid seal*

PART SERIAL	119	184	193
INLET TEMP	100.4 C	100.9 C	101.4 C
INLET PRESSURE	0.025 Torr	0.029 Torr	0.028 Torr
H	0.0000	0.0000	0.0000
HE3	0.0000	0.0000	0.0000
HE4	0.0000	0.0001	0.0001
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H2O	1.0924	0.4435	0.4849
NE20	0.0000	0.0000	0.0000
NE22	0.0000	0.0000	0.0000
N	91.1979	92.0403	91.2011
CO	0.0000	0.0000	0.0000
O	0.0538	0.2804	0.1127
AR	0.0053	0.0161	0.0018
CO2	0.2584	0.1915	0.2617
TotHCOrg	0.6257	0.5821	0.7802
Fluorocarbons	0.0075	0.0027	0.0143
NH3	0.1580	0.2762	0.3062
KR	0.0000	0.0000	0.0000
XE	0.0000	0.0000	0.0000

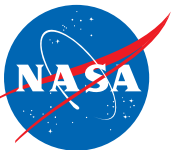
*IGA results of three packages with lid seals showing voids >80%  
IGA results show a hermetically sealed device*



# Is there a long-term concern with lid seal voids?

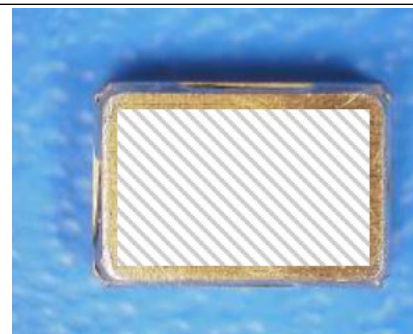
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- Review of NASA GSFC's failure analyses investigations into EEE parts showed no examples of part failures traced to loss of hermeticity due to voids in the lid seal
  - Review of data for years 2010 – 2021
  - In contrast, there were failures of EEE parts traced to loss of hermeticity for reasons other than lid seal voids
- Proposed test:
  1. Locate parts with lid seal voids in excess of 75% lid seal void criteria, but verified to be hermetic
  2. Subject parts to conditions that are most likely to stress a solder joint – temperature cycling -55C to +125C
  3. Re-check hermeticity of parts
  4. Perform IGA to check internal gasses for signs of air ingress

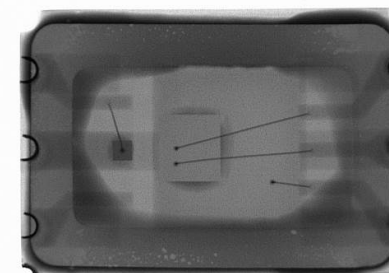


# Examining Hermeticity Stability of Parts with Lid Seal Voids

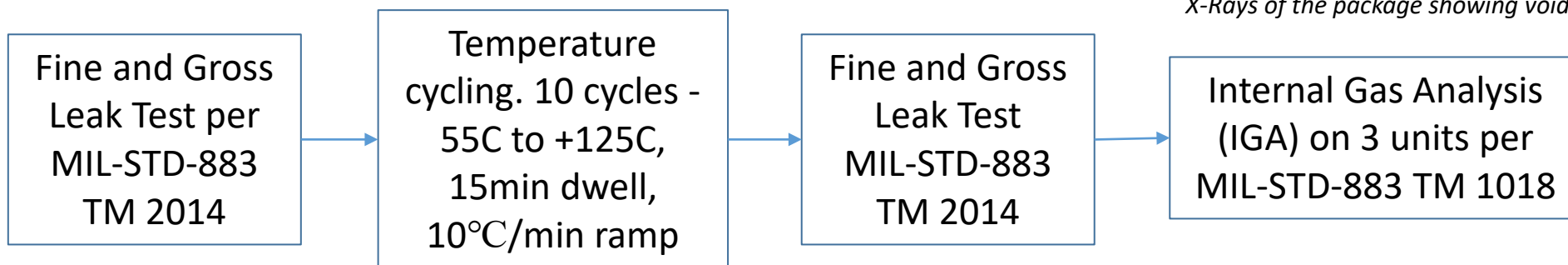
- Background of parts
  - A commercial device screened to MIL-STD-883
  - Package style: UBA
  - Hermeticity test at manufacturer results: fine leak (147 passed/1 failed) and gross leak (147 passed/0 failures) passed.
  - X-Ray of 30 received units showed all units with lid seal voids in excess of 75%, with many units showing lid seal voids spanning 95% of the seal
- Test Plan
  - 30 units with lid seal voids in excess of 75%, and 5 control units with lid seal passing MIL-STD-883 TM2012 criteria

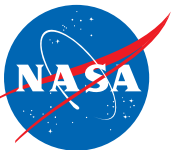


*Optical image of the device (part markings removed)*

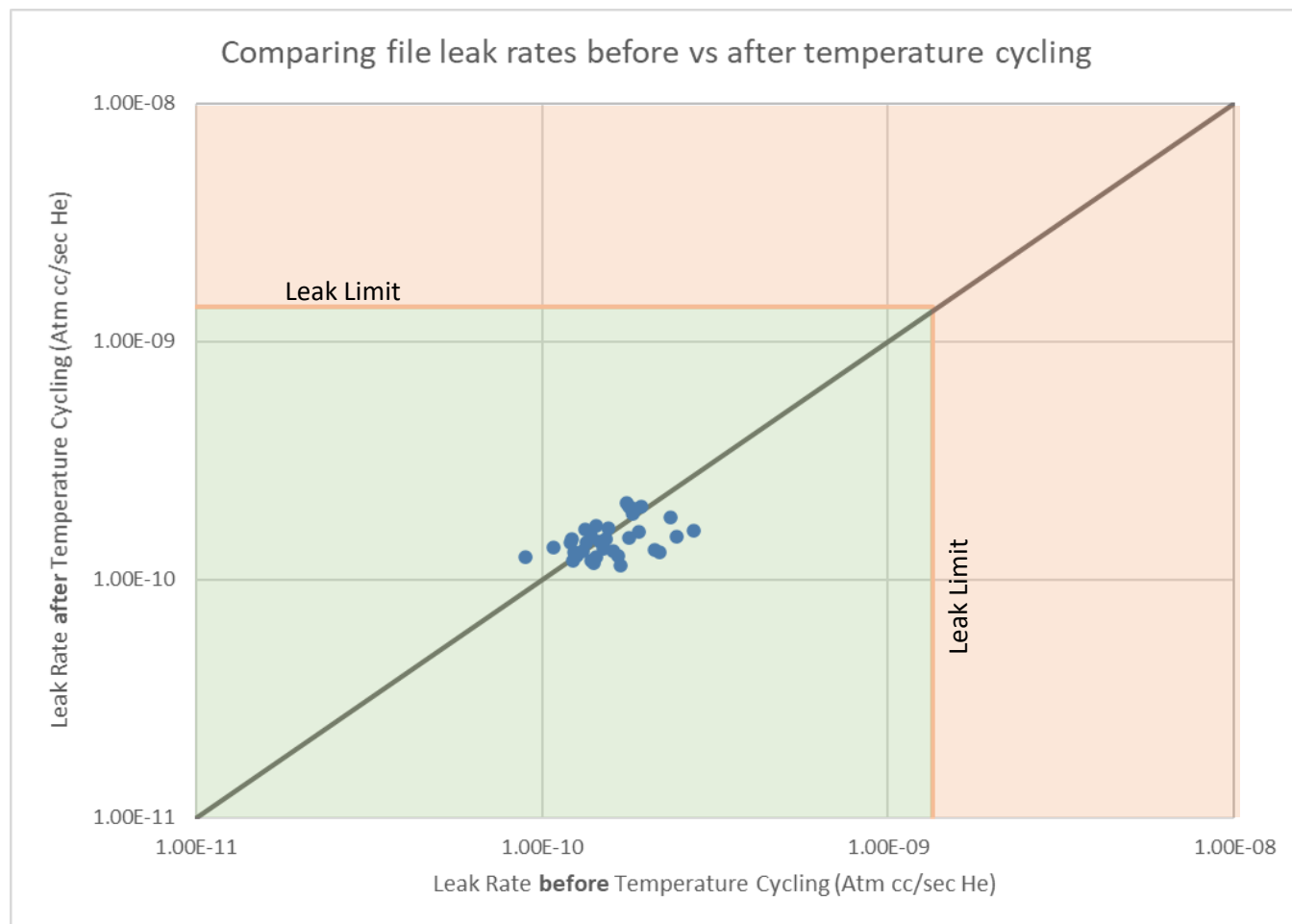


*X-Rays of the package showing void in solder lid seal*





# Hermeticity Testing Before and After Temperature Cycling



- 35 units tested for fine and gross leak before and after temperature cycling
  - 30 units with lid seal voids >75%
  - 5 units with lid seal voids <75%, as controls
- All units passed fine and gross leak before and after temperature cycling
- Fine leak measurements show consistency before and after temperature cycling
- Notes on graph:
  - Red area on the graph for leak rates failing fine leak limit
  - Green area on the graph for leak rates passing fine leak limit
  - Grey diagonal line – readings on the line mean there was no change before and after temperature cycling

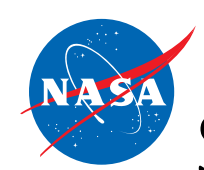


# IGA Results After Temperature Cycling

SAMPLE ID		017	103	050
Pass/Fail		FAIL	FAIL	FAIL
Inlet Pressure	torr	N/A	N/A	N/A
Sys. Pressure	torr	9.4e-6	1.0e-5	9.5e-6
Sample Temp.	°C	100.1	100.2	100.8
Volume	cc	0.005	0.005	0.005
Nitrogen	ppmv	952,410	961,438	948,474
Oxygen	ppmv	ND	ND	ND
Argon	ppmv	ND	ND	ND
Carbon Dioxide	ppmv	4,226	3,349	3,435
Moisture	ppmv	31,585	24,920	37,006
Hydrogen	ppmv	3,125	2,733	2,757
Methane	ppmv	8,654	7,559	8,328
Ammonia	ppmv	ND	ND	ND
Helium	ppmv	ND	ND	ND
Fluorocarbon	ppmv	ND	ND	ND

- Three (3) units submitted for Internal Gas Analysis (IGA) after temperature cycling. All three units are X-ray rejects per MIL-STD-883 TM2012 with lead seal voids in excess of 95%
- All units show no signs of air ingress: oxygen and argon levels are undetectable. If air was present, expected to see 20:1 ratio of oxygen:argon
  - Note: ND stands for non-detectable
- All units show no signs of helium ingress from helium fine leak test
- Moisture readings in excess of 5,000ppmv limit. However, the parts are known to be sealed with moisture-outgassing materials on the inside – an optical light pipe

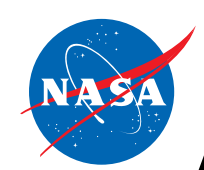




# Summary

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- Lid seal voids in excess of 75% per MIL-STD-883 TM 2012 3.10.2.2.e criteria are not uncommon
- Review of failure analyses at NASA GSFC between 2010-2021 shows no examples of part failures due to loss of hermeticity traced to lid seal voids
- Temperature cycling of devices with lid seal voids in excess of 95% showed no effect on hermeticity, and subsequent IGA testing showed parts retained hermetic seal
  - Test conditions: 10 temperature cycles, -55°C to +125°C, 15min dwell, 10°C/min ramp
- Hermeticity testing is recommended to judge acceptability of parts with lid seal voids



# Acronyms

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He	Helium
GSFC	Goddard Space Flight Center
IGA	Internal Gas Analysis
NASA	National Aeronautics and Space Administration
N/A	Not Applicable
ND	Not Detected
MIL-STD	Military Standard
TM	Test Method